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EXPERIEMENTAL STUDIES ON OPTIMIZATION OF MOLDING SAND COMPOSITION WITH TAMARIND KERNEL POWDER AS ADDITIVE

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ABSTRACT

Among all the manufacturing processes, sand casting process still remains as one of the most complex process as it involves heat transfer, fluid flow and so many other things. As the properties of the green sand mix influence the casting defects, the parameters affecting these properties should be identified and controlled precisely. Since, Traditional method of trial-and-error based methods have many disadvantages such as being nonsystematic, time consuming, error-prone and requirement for long durations of experimentation [1], statistical techniques are to be employed. The process parameters that are being varied are clay, water and additive. L-9 orthogonal array is used for experimental design and S/N ratio, and ANOVA are employed to find the optimal process parameter levels and to analyze the effect of these parameters on green compression strength, green shear strength, dry compression strength, dry shear strength, and permeability. Confirmation test with the optimal levels of machining parameters was carried out.

KEYWORDS: ANOVA, Tamarind Kernel & Molding Sand

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Original Article

1. INTRODUCTION

Although there are many new advanced technologies for metal casting, green sand casting remains one of the most widely used casting processes today due to the low cost of raw materials, a wide variety of castings with respect to size and composition, and the possibility of recycling the molding sand. Over many decades, researchers focused on identifying process factors effecting sand mold properties. The composition of molding sand mixture was very vital to the properties of sand mold [2].

In this work, an attempt made for optimizing the clay, water and additive contents in the green sand used for moulding with Taguchi method usingAnalysis of variance (ANOVA) method and Signal to noise(S/N) ratio method. L-9 orthogonal array is used here to obtain 9 specimens. The parameters that are being varied are clay, water and tamarind kernel powder. The outputs being monitored are green compression and shear strengths, dry compression and shear strengths, permeability. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications [3,4,5]. The levels chosen for input parameters are presented in Table 1.

Table 1: Process Parameters and their Levels

Parameters	Level-1	Level-2	Level-3
Clay	5%	8%	11%
Water	3%	5%	7%
Additive	0.8%	1%	1.2%

The values of the parameters are assigned to standard orthogonal array and presented in table 2

Table 2: Assigned Orthogonal Array

Specimen	Clay (%)	Water (%)	Additive (%)
1	5	3	0.8
2	5	5	1
3	5	7	1.2
4	8	3	1.2
5	8	5	0.8
6	8	7	1
7	11	3	1
8	11	5	1.2
9	11	7	0.8

2. EXPERIMENTATION

Using assigned L-9 array, 27 experiments have to be conducted for 9 combinations (3 repetitions for each case).

To maintain uniform grain fineness number thought out the experimentation, sand is sieved trough the sieves with ASTM number 35 and 100. The sand retained between these sieves is used for preparing the specimens. Specimens were prepared and the Green Compressive Strength, Green shear strength, Dry compression strength and Dry shear strength are tested by the Universal Sand Strength Machine and permeability is tested on permeability meter and the results are presented in table 3, Table 4 and Table 5.

Table 3: GCS and GSS Values of Various Trials

Specimen	Clay	Water	Additive	GCS gm/cm^2			GSS gm/cm^2		
				1	2	3	1	2	3
1	**5**	**3**	**0.8**	196.896	203.928	210.96	70.32	84.38	70.32
2	**5**	**5**	**1**	207.44	200.41	210.96	77.35	84.38	77.35
3	**5**	**7**	**1.2**	168.76	161.73	182.83	70.32	63.28	63.28
4	**8**	**3**	**1.2**	492.24	527.4	492.24	133.60	126.57	140.64
5	**8**	**5**	**0.8**	337.53	326.98	337.53	133.60	140.64	140.64
6	**8**	**7**	**1**	341.05	337.53	337.53	154.70	154.70	161.73
7	**11**	**3**	**1**	559.04	566.07	569.59	147.67	147.67	154.70
8	**11**	**5**	**1.2**	590.68	576.62	583.65	182.32	175.8	189.86
9	**11**	**7**	**0.8**	481.69	485.20	478.17	225.02	217.99	225.02

Table 4: DCS and DSS Values of Various Trials

Specimen	Clay	Water	Additive	DCS gm/cm^2			DSS gm/cm^2		
				1	2	3	1	2	3
1	**5**	**3**	**0.8**	2074.44	1968.96	2018.18	1314.98	1300.92	1286.856
2	**5**	**5**	**1**	1511.88	1582.2	1547.04	738.36	752.42	696.16
3	**5**	**7**	**1.2**	6574.92	6574.92	6574.92	2672.16	2566.68	2672.16
4	**8**	**3**	**1.2**	984.48	998.54	984.48	562.56	562.56	562.56
5	**8**	**5**	**0.8**	6574.92	6574.92	6574.92	2095.53	2123.66	2109.6
6	**8**	**7**	**1**	7172.64	7172.64	7172.64	2496.36	2531.52	2637
7	**11**	**3**	**1**	1687.68	1687.68	1687.68	562.56	569.59	562.56
8	**11**	**5**	**1.2**	3867.6	3867.6	3867.6	984.48	998.54	1012.60
9	**11**	**7**	**0.8**	7453.92	7453.92	7453.92	3058.92	3023.76	3094.08

Table 5: Permeability Values of Various Trials

Specimen	Clay	Water	Additive	Permeability		
				1	2	3
1	**5**	**3**	**0.8**	572.89	570.32	574.51
2	**5**	**5**	**1**	859.33	855.21	860.81
3	**5**	**7**	**1.2**	316.09	314.18	316.5
4	**8**	**3**	**1.2**	330.51	330.81	332.9
5	**8**	**5**	**0.8**	505.49	504.21	504.8
6	**8**	**7**	**1**	422.13	423.1	422.55
7	**11**	**3**	**1**	259.43	260.8	257.5
8	**11**	**5**	**1.2**	301.18	302.3	302.1
9	**11**	**7**	**0.8**	268.75	267.6	265.3

3. ANALYSIS OF THE RESULTS

ANOVA is carried out to identify the most effective parameters and presented in table 6 to table 10.

Table 6: ANOVA Results for GCS

Parameter	SS	DOF	V	F	P
CLAY	74.16898	2	37.08449	16.74849	58.10811
WATER	5.333333	2	2.666667	1.204348	4.178431
ADDITIVE	3.853333	2	1.926667	0.870142	3.018916
SSR	83.35565	6	13.89261		
SST	127.6396	26	4.909217		
SSE	44.28398	20	2.214199		34.69454

Table 7: ANOVA Results for GSS

Parameter	SS	DOF	V	F	P
CLAY	7.573704	2	3.786852	14.36328	55.89602
WATER	0.507037	2	0.253519	0.961579	3.742073
ADDITIVE	0.195926	2	0.097963	0.371567	1.445987
SSR	8.276667	6	1.379444		
SST	13.54963	26	0.52114		
SSE	5.272963	20	0.263648		38.91592

Table 8: ANOVA results for DCS

Parameter	SS	DOF	V	F	P
CLAY	553.9737	2	276.9869	0.355581	1.541724
WATER	18361.36	2	9180.682	11.78567	51.10017
ADDITIVE	1437.37	2	718.6852	0.92261	4.00024
SSR	20352.71	6	3392.118		
SST	35932.1	26	1382.004		
SSE	15579.39	20	778.9696		43.35787

Table 9: ANOVA results for DSS

Parameter	SS	DOF	V	F	P
CLAY	0.133704	2	0.066852	0.000648	0.002848
WATER	2285.28	2	1142.64	11.08183	48.671
ADDITIVE	347.7633	2	173.8817	1.686382	7.406527
SSR	2633.177	6	438.8628		
SST	4695.363	26	180.5909		
SSE	2062.186	20	103.1093	103.1093	43.91963

Table 10: ANOVA results for permeability

Parameter	SS	DOF	V	F	P
Clay	281087.5	2	140543.8	4.919957	30.78988
Water	8302.735	2	4151.367	0.145325	0.909468
Additive	52210.42	2	26105.21	0.913854	5.719046
SSR	341600.7	6	56933.45		
SST	912921.8	26	35112.38		
SSE	571321.1	20	28566.06		62.5816

From the table 6 to 10, it can be concluded that clay has maximum contribution of 58.108% in GCS at 99% confidence level, clay has maximum contribution of 30.78% in permeability at 97.5% confidence level, and clay has maximum contribution of 55.89% in GSS at 99% confidence level. Water has maximum contribution of 51.1% in DCS at 99% confidence level; water has maximum contribution of 48.67% in DSS at 99% confidence level.

S/N Analysis is carried out considering the GCS, GSS, DCS, DSS and permeability are as the quality characteristics with the concept of "the larger-the-better". The S/N ratio used for this type response is given by:

The S/N ratio for the larger-the-better is represented by equation (1)

$$\eta = -10log_{10}[\frac{1}{n}\sum_{i=1}^{n} y_i{}^2] \ldots\ldots \quad (1)$$

Where n is the number of measurements in a trial/row, in this case, n=3 and y is the measured value in a run/row.

Table 11: S/N Results for GCS

	Clay	Water	Additive	GCS			S/N
1	1	1	1	196089	203.92	210.96	46.179
2	1	2	2	207.44	200.41	210.96	46.2828
3	1	3	3	168.76	161.73	182.83	44.6319
4	2	1	3	492.24	527.4	492.24	54.0343
5	2	2	1	337.53	326.98	337.53	50.4723
6	2	3	2	341.05	337.53	337.53	50.5961
7	3	1	2	559.04	566.07	569.59	55.0386
8	3	2	3	590.68	576.62	583.65	55.3218
9	3	3	1	481.69	485.2	478.17	53.6548

Table 12: S/N Analysis for GCS

	clay	water	additive
S1	137.0937	155.2519	150.3062
S2	155.1027	152.0769	151.9175
S3	164.0153	148.8828	153.9879
Range	26.92161	6.36908	3.681769

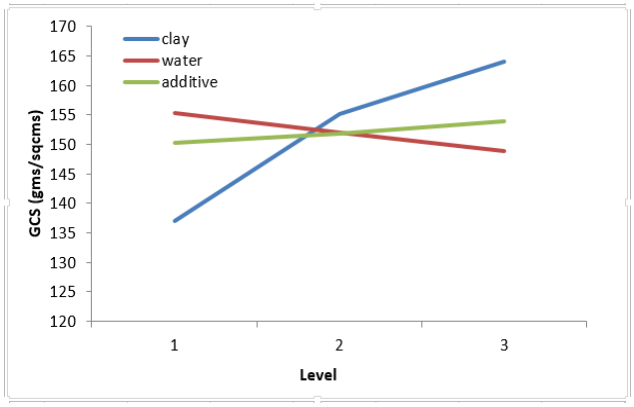

Figure 1: S/N Response for GCS

From the table 11& 12 and Figure 1, it can be concluded that the optimum condition for maximum GCS is level 3 of clay, level 1 of water and level 3 of additive, i.e., 11% of clay, 3% of water, and 1.2% of additive.

Table 13: S/N results for GSS

	Clay	Water	Additive	GSS			S/N
1	1	1	1	70.32	84.38	70.32	37.40799
2	1	2	2	77.35	84.38	77.35	38.00676
3	1	3	3	70.32	63.28	63.28	36.3098
4	2	1	3	133.6	126.57	140.64	42.49222
5	2	2	1	133.6	140.64	140.64	42.80835
6	2	3	2	154.7	154.7	161.73	43.9147
7	3	1	2	147.67	147.67	154.7	43.51637
8	3	2	3	182.83	175.8	189.86	45.22809
9	3	3	1	225.02	217.99	225.02	46.95057

Table 14: S/N Analysis for GSS

	Clay	Water	Additive
S1	111.7245	123.4166	127.1669
S2	129.2153	126.0432	125.4378
S3	135.695	127.1751	124.0301
Range	23.97049	3.758485	3.136797

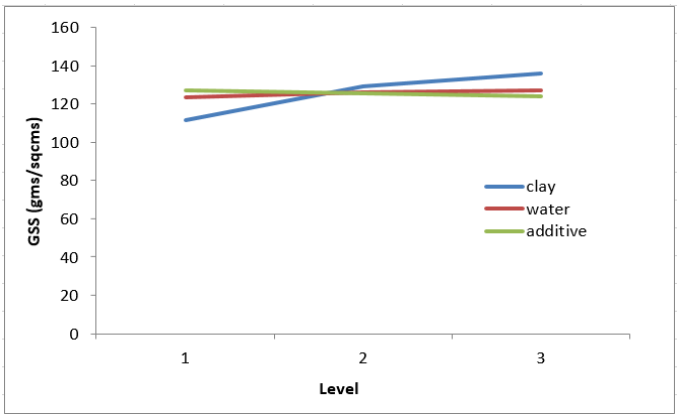

Figure 2: S/N Response for GSS

From the above results, it can be concluded that the optimum condition for maximum GSS is level 3 of clay, level 3 of water and level 1 of additive, i.e., 11% of clay, 7% of water, and 0.8% of additive.

Table 15: S/N results for DCS

	Clay	Water	Additive	DCS			S/N
1	1	1	1	2074.44	1968.96	2018.18	66.1034
2	1	2	2	1511.88	1582.2	1547.04	63.7855
3	1	3	3	6574.92	6574.92	6574.92	76.3578
4	2	1	3	984.48	998.54	984.48	59.9048
5	2	2	1	6574.92	6574.92	6574.92	76.3578
6	2	3	2	7172.64	7172.64	7172.64	77.1136
7	3	1	2	1687.68	1687.68	1687.68	64.5458
8	3	2	3	3867.6	3867.6	3867.6	71.7488
9	3	3	1	7453.92	7453.92	7453.92	77.4477

Table 16: S/N Analysis for GSS

	Clay	Water	Additive
S1	206.2467	190.554	219.9089
S2	213.3762	211.8922	205.4449
S3	213.7423	230.9191	208.0114
Range	7.495599	40.3651	14.46395

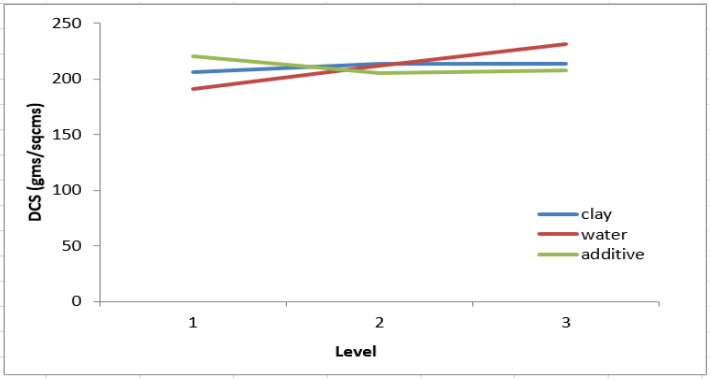

Figure 3: S/N Response for GSS

From the above results, it can be concluded that the optimum condition for maximum DCS is level 3 of clay, level 3 of water and level 1 of additive, i.e., 11% of clay, 7% of water, and 0.8% of additive.

Table 17: S/N results for DSS

	Clay	Water	Additive	DSS			S/N
1	1	1	1	1314.98	1300.92	1286.85	62.284
2	1	2	2	738.36	752.42	696.16	57.24
3	1	3	3	2672.16	2566.68	2672.16	68.4175
4	2	1	3	562.56	562.56	562.56	55.0034
5	2	2	1	2095.53	2123.66	2109.6	66.4836
6	2	3	2	2496.36	2531.52	2637	68.1407
7	3	1	2	562.56	569.59	562.56	55.039
8	3	2	3	984.48	998.54	1012.6	59.9856
9	3	3	1	3058.92	3023.76	3094.08	69.7102

Table 18: S/N Analysis for DSS

	clay	water	additive
S1	187.9414	172.3264	198.4778
S2	189.6276	183.7092	180.4197
S3	184.7348	206.2684	183.4065
Range	4.892809	33.94198	18.05813

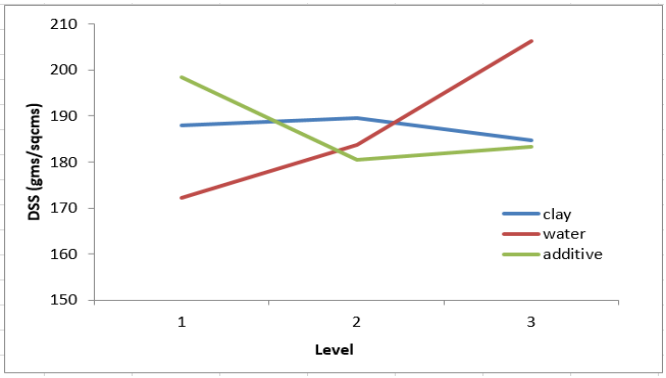

Figure 4: S/N Response for DSS

From the above results, it can be concluded that the optimum condition for maximum DSS is level 2 of clay, level 3 of water and level 1 of additive, i.e., 8% of clay, 7% of water, and 0.8% of additive.

Table 19: S/N results of permeability

	Clay	Water	Additive	PERMEABILITY			S/N
1	1	1	1	572.89	570.32	574.51	55.1565
2	1	2	2	859.33	855.21	860.81	58.6742
3	1	3	3	316.09	314.18	316.5	49.9823
4	2	1	3	330.51	330.81	332.9	50.4071
5	2	2	1	505.49	504.21	504.8	54.0629
6	2	3	2	422.13	423.1	422.55	52.5184
7	3	1	2	259.43	260.8	257.5	48.2738
8	3	2	3	301.18	302.3	302.1	49.5961
9	3	3	1	268.75	267.6	265.3	48.5369

Table 20: S/N Analysis for Permeability

	clay	water	additive
S1	163.813	153.8374	157.7563
S2	156.9885	162.3332	159.4664
S3	146.4068	151.0377	149.9855
Range	17.40627	11.29556	9.480939

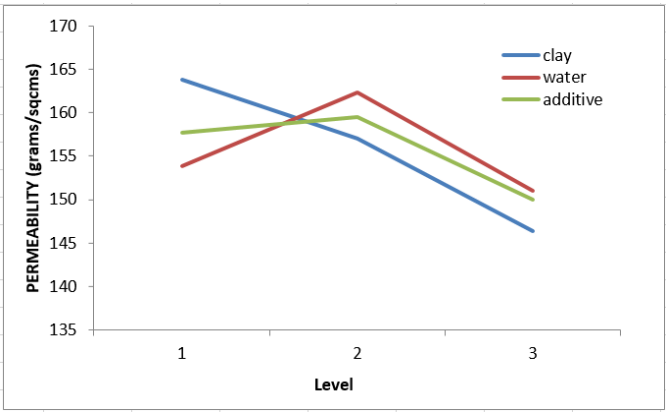

Figure 5: S/N Response for Permeability

Therefore, from the above results it can be concluded that the optimum condition for maximum permeability is level 1 of clay, level 2 of water and level 2 of additive, i.e., 5% of clay, 5% of water, and 1% of additive.

4. CONCLUSIONS

This study has discussed an application of the Taguchi method for investigating the effects of parameters on the characteristics of the molding sand. From the analysis of the results using the conceptual signal-to-noise (S/N) ratio approach, analysis of variance (ANOVA) and Taguchi's optimization method, the following can be concluded from the present study:

- Clay has maximum contribution of 58.108% in GCS at 99% confidence level. The optimum condition for maximum GCS is 11% of clay, 3% of water, and 1.2% of additive.
- Clay has maximum contribution of 55.89% in GSS at 99% confidence level. The optimum condition for maximum GSS is 11% of clay, 7% of water, and 0.8% of additive.
- Water has maximum contribution of 51.1% in DCS at 99% confidence level. The optimum condition for maximum DCS is 11% of clay, 7% of water, and 0.8% of additive.
- Water has maximum contribution of 48.67% in DSS at 99% confidence level. The optimum condition for maximum DSS is 8% of clay, 7% of water, and 0.8% of additive.
- Clay has maximum contribution of 30.78% in permeability at 97.5% confidence level. The optimum condition for maximum permeability 5% of clay, 5% of water, and 1% of additive.

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